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Stella L. Volpe

Hati Kobusingye

Smita Bailfur

Edward J. Stanek, *University of Massachusetts - Amherst*

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Original Research

Effect of Diet and Exercise on Body Composition, Energy Intake and Leptin Levels in Overweight Women and Men

Stella L. Volpe, PhD, Hati Kobusingye, MS, Smita Bailur, MS, Edward Stanek, PhD

University of Pennsylvania, Division of Biobehavioral and Health Sciences (S.L.V.), Philadelphia, Pennsylvania, Department of Nutrition, Chenoweth Laboratory (H.K., S.B.), Department of Biostatistics and Epidemiology, Arnold House (E.S.), University of Massachusetts, Amherst, Massachusetts

Key words: body weight, diet, exercise, leptin, lipids

Objective: To investigate the effect of diet alone (D), exercise alone (E), and a combination of diet and exercise (DE) on body weight, body composition, energy intake, blood pressure, serum lipid and leptin levels, and fitness levels in mildly obese sedentary women and men.

Design: The three interventions were compared in a randomized longitudinal study design. The exercise programs were supervised for six months, after which participants in E and DE were provided with exercise equipment to take home.

Subjects: 90 adult overweight women and men (age: 44.2 ± 7.2 years; BMI = 30.5 ± 2.7 kg/m²).

Measurements: Body weight, body composition, waist and hip circumferences, blood pressure, serum lipid levels, and fitness levels were evaluated at 0, 3, 6, 9, and 12 months. Serum leptin concentrations were measured at 0 and 6 months only.

Results: At 6 and 9 months in women, and 9 months in men, DE demonstrated a significant loss of body weight compared to both D and E ($p < 0.05$). Serum leptin levels significantly decreased from baseline to 6 months in women in D ($p = 0.05$) and DE ($p = 0.0003$) and men in E ($p = 0.038$). At one year, no significant differences existed among groups in any of the measures.

Conclusion: A combination of diet and exercise resulted in a significant decrease in body weight in women and men; but this decrease was not maintained at one year follow-up. Serum leptin concentrations showed significant within-group decreases, but were not different among groups. A supervised diet and exercise program is effective for weight loss; however, once intensive participant-investigator and participant-participant contact is discontinued, weight regain ensues.

INTRODUCTION

Approximately one-third of the population in the United States (U.S.) between 20 to 74 years of age are considered obese [1]. It is becoming increasingly clear that weight loss can be achieved and maintained through dietary changes and exercise programs [2]. Obesity treatment programs that rely solely on diets, especially those that are severely restrictive with regard to choices, have poor long-term outcomes; within two or three years, most participants regain all of the weight lost [3].

In short-term studies, the combination of diet and exercise has been assumed to be the optimal treatment for obesity [3]. Long-term follow-up studies suggest that people who exercise regularly achieve better maintenance of weight loss [3] and better metabolic fitness (e.g., improved lipid levels, blood pressure). The effectiveness of exercise on body weight and metabolic fitness may be influenced by the type, intensity, frequency and duration of exercise [4], and may also be a result of interaction with others in a program and/or with those providing the exercise program.

Address reprint requests to: Stella L. Volpe, PhD, RD, LDN, FACSM, University of Pennsylvania, School of Nursing, Division of Biobehavioral and Health Sciences, Claire M. Fagin Hall, 418 Curie Boulevard, Philadelphia, PA 19104-6096. E-mail: svolpe@nursing.upenn.edu

Institutional affiliation of all authors at the time of the study was the University of Massachusetts, Amherst.

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In addition to the effects that exercise and diet may have on body weight, exercise and diet may affect leptin concentrations. Higher leptin levels have been associated with greater body fat. Furthermore, leptin has been shown to be affected by diet and exercise [5,6]; however, little research has been conducted on the effects of a long-term, supervised exercise and diet program on serum leptin concentrations.

The purpose of this study was to examine the effects of combining a heart-healthy, lower energy diet with a supervised exercise program on: body weight, body composition, blood pressure, serum lipid and leptin levels, and fitness levels over a one-year period. This regimen was compared to both diet and exercise alone. This study is unique for several reasons: 1) there were supervised and unsupervised phases, in which the intensive investigator-to-participant and participant-to-participant contact decreased gradually over the one-year period, 2) comprehensive cardiovascular measurements, including lipid levels and blood pressure, were made, and 3) serum leptin concentrations were assessed.

METHODS

Experimental Design

The study protocol was approved by the University of Massachusetts Human Subjects Review Committee prior to subject selection. Ninety subjects (46 pre- or peri-menopausal women and 44 men), 24 to 62 years of age, were recruited by advertisements placed in the University and local newspapers. Subjects: 1) were sedentary (exercising no more than one day per week), 2) were non-smokers, 3) had a body mass index (BMI) (kg/m^2) between 27 and 35 kg/m^2 (mild to moderately obese), 4) had not recent acute illness or trauma (within the last six months), 5) had no history of cardiovascular disease, hypertension, hyper- or hypothyroidism, or any other type of chronic disease, 6) were not on a weight reduction program (within the last three months), and 7) were not taking any supplements for weight reduction (e.g., physician prescribed or over-the-counter pills, powders, etc.) within the last three months.

Participants were randomly assigned, in a stratified manner based on BMI, to one of three treatment conditions: diet only (D) ($n = 28$), exercise only (E) ($n = 34$), or a combination of diet and exercise (DE) ($n = 28$). Measurements were performed at baseline, three (Phase 1), six (Phase 2), nine months (Phase 3), and 12 months (follow-up).

Timepoints for Data Collection

Baseline Period. All subjects participated in this period for one to two weeks. The following variables were collected during the baseline period: height, body weight, BMI, percent body fat, waist and hip circumferences, resting blood pressure,

blood for serum lipid and leptin concentrations, three-day dietary records. During this baseline period all subjects were habituated to the NordicTrack™ indoor skiing apparatus. They were required to exercise at one of two designated facilities, whichever was more convenient for them. They were initially trained for one to two weeks, about 10 minutes each session, so as not to elicit a training effect, but to learn how to use the indoor skiing apparatus. All subjects' fitness levels were then measured by using the NordicTrack™ Home Fitness Test [7].

Phase 1 (0 to 3 Months). During this 12-week period, subjects in E and DE were supervised throughout all exercise sessions by trained graduate or undergraduate students. Participants exercised three days per week for six weeks, increasing to a total of four, 30-minute sessions per week for six weeks. At each exercise session, initial heart rate and leg tension on the skiing apparatus were recorded. After 15 and 30 minutes, heart rate and mileage covered on the skiing apparatus were recorded. A final heart rate was taken 10 minutes after the completion of each exercise session to ensure proper cool down.

Intensive (weekly) nutritional classes also occurred during this period for subjects in D and DE. The topics that were covered are listed in Table 1. The goal was for participants to lose 0.5 to 1.0 kg of body weight per week. At the end of this period, all of the aforementioned measures were taken again (except blood for leptin analysis).

Phase 2 (4 to 6 Months). During this 12-week period, subjects in E and DE continued to exercise. The exercise sessions continued to be supervised by trained graduate or undergraduate students. Subjects increased their exercise sessions to five days per week 30 minutes per session (i.e., six weeks at four times per week, then six more weeks at five times per week). Subjects in D and DE continued to attend nutrition

Table 1. Topics Covered in the Nutrition Classes Attended by the Diet and Diet Plus Exercise Groups

Session	Topic
1	Introduction
2	Energy Needs
3	Weight Management
4	Fat Intake
5	Food Labeling
6	Dieting
7	Hunger
8	Weight Maintenance
9	Fiber Intake
10	Eating Out
11	Effectiveness of Weight Loss and Thermogenic Agents
12	Metabolism
13	Antioxidants
14	Miscellaneous Questions/Comments
15	Vegetarianism
16	Fats, Carbohydrates, Proteins
17	Food Shopping
18	Questions

classes on adhering to a lower energy, heart-healthy diet, but the sessions were lessened to every other week. At the end of this period, all of the aforementioned measures were taken again.

Phase 3 (7 to 9 Months). During this 12-week period, subjects in E and DE each received a skiing apparatus to exercise at home; however, contact with the investigators was minimal. Phone calls and/or e-mail messages were made to each subject on a monthly basis to ensure that they were exercising and/or adhering to a lower energy, heart-healthy diet regimen. Thus, the nutrition classes for D and DE no longer continued, but were minimized to the phone calls or e-mail messages, as well. At the end of this period, all of the aforementioned measures were taken again (except blood for leptin analysis) and subjects were required to record their dietary intake for three days. The NordicTrack™ Home Fitness Test [7] was also conducted in all subjects.

Follow-Up at 12 Months. Following the end of Phase 3, the investigators continued to contact the subjects periodically by phone and/or e-mail, to inquire about the subjects' ability to adhere to the diet, exercise, or diet plus exercise regimens. At 52 weeks, follow-up measures of all the aforementioned variables were performed (except blood for leptin analysis) to establish whether the subjects maintained their diet, exercise, or diet plus exercise regimens.

Anthropometric Measures

All procedures were performed at baseline and at the end of each phase. Height was measured to the nearest 0.5 cm. Body weight was measured on a balance-beam scale accurate to ± 0.5 kg while the subject was wearing a swimsuit and no shoes.

Body density was calculated by hydrostatic weighing based on the method of McArdle et al. [8] Residual lung volume was measured as 28% vital capacity for women and 24% vital capacity for men. Vital capacity of the subjects was measured using a Gould Spiroscreen spirometer (Vacumetrics, Ventura, CA). Percent body fat was calculated from body density using the Siri equation [9].

Circumferences of the waist and hip were measured three times at each site. Waist was taken using the smallest circumference between the pelvis and ribcage. Hip were taken as the largest circumference below the waist. The waist-to-hip ratio was calculated by dividing the waist circumference by the hip circumference.

Blood Pressure

Resting systolic and diastolic blood pressure was measured by a registered nurse using a calibrated sphygmomanometer. Measurements were taken from the left upper arm in a sitting position. All measurements were completed after subjects were seated for about five minutes.

Laboratory Procedures

Blood Collection. Prior to giving blood, all subjects fasted for twelve hours (overnight). Blood was drawn by a registered nurse. All blood collections were done via venipuncture in the antecubital vein with the subjects in a sitting position. About 30 mL of blood was drawn from every subject at each test session. The blood was collected in Vacutainer blood collection tubes (Becton Dickinson, Franklin Lakes, NJ). Following the blood collection, serum blood samples were allowed to clot on ice for one hour. Red blood cells were separated from serum by centrifugation at 3000 rpm ($1500 \times g$) for 15 minutes. The clear supernatant was aliquoted into properly labeled 1.5 mL Eppendorf (Outpatient Services, Petaluma, CA) tubes, using mineral free disposable transfer pipettes. The Eppendorf tubes were stored at -80°C until required for all analyses.

Serum Lipid Concentrations. Serum total cholesterol (TC), serum high density lipoprotein cholesterol (HDL-C), serum low density lipoprotein cholesterol (LDL-C) and serum triglyceride (TG) [10] concentrations were all assessed at SmithKline Beecham Clinical Laboratories (Waltham, MA). Serum TC, HDL-C, and TG levels were measured using the Olympus® AU5200 (Olympus America Inc., Melville, NY), which employed a series of coupled enzymatic reactions. LDL-C levels were calculated by using the formula: $\text{LDL-C (mg/dL)} = \text{TC} - \text{serum high density cholesterol (HDL-C) levels} - \text{serum very low density lipoprotein cholesterol (VLDL-C) levels}$ [11] (Olympus® brochure, OHL2021, 1997). Note that VLDL-C will not be reported but was assessed for solely for calculation.

Serum Leptin Concentrations. Serum leptin levels were measured using an Enzyme Linked ImmunoSorbent Assay (ELISA). The procedure for analyses were followed as per R&D Systems' (Minneapolis, MN) instruction manual. Serum leptin concentrations were measured at baseline and six months only.

Fitness Test

Physical fitness of each subject was tested by the NordicTrack™ Home Fitness Test [7]. Each subject received instructions on the proper use of the indoor skiing apparatus. Prior to any exercise, initial heart rate was taken. This was done by taking a radial or carotid pulse for six seconds, timed by the investigator. Subjects exercised continuously for a distance of one mile which was recorded on the computer of the indoor skiing apparatus. Immediately upon completion of the mile, heart rate was taken. The total exercise time corresponding to the distance of one mile was recorded from the computer of the machine. The subject then rested for about five minutes after which his or her heart rate was taken once again. Fitness measurements were not a primary outcome, but were assessed to ensure that the exercise was sufficient to elicit increased fitness, and that D did not perform an amount of exercise that would improve their fitness levels during the study.

Dietary Assessment

After each testing session subjects completed a three-day diet record. Subjects were taught how to properly complete their three day dietary records. The three day diet record consisted of two weekdays and one weekend day. All the records were collected and analyzed for total energy, fat, carbohydrate and protein intake using the University of Massachusetts Nutrient Data Bank (Amherst, MA).

Statistical Analyses

Sample Size Calculations. Sample size calculations were conducted assuming a two-sided test and 0.05 level of significance. We based the sample size calculation on the assumption that 13 participants (accounting for men and women separately) in each group would complete the study, for a total of 78 participants; however, 90 subjects were recruited to anticipate for a 10% attrition rate. Our statistical methods allowed for a variable number of observations per participant, so that partial information collected on participants who were lost to follow-up were used in analyses. Our sample size justifications are based on the conservative assumption that analyses will be based only on participants with complete information. With 78 total subjects and a two-sided type one error of 5%, we had 80% power.

A repeated measures analysis of covariance (ANCOVA) with baseline measurements as the covariate was used to calculate changes between and within groups over time. Scheffe's multiple comparisons were performed if significant main effects or interactions existed. Results were analyzed for men and women separately and will be presented as such. All data were

analyzed using SAR^R System for Microsoft windows, release 6.12, 1996 (SAS Institute Inc. Cary, NC).

RESULTS

Table 2 presents baseline comparisons among groups for women and men. For women, height in D was significantly greater than E, whereas LBM in DE was significantly greater than E and DE at baseline. Height among men in DE was significantly greater than both D and E. No significant differences were observed in age, body weight, BMI, percent body fat, and fat mass among women and men at baseline. In addition, no significant differences were observed among groups in men for LBM at baseline.

Anthropometric Measures

DE in women had a significantly lower body weight than both D and E at phase 2. In addition, DE had a significantly lower body weight than D and E at phase 3 (Fig. 1). Within DE (women), body weight at phase 2 and phase 3 was significantly lower than phase 1.

Body weight of DE in men was significantly lower than both D and E at phase 3 (Fig. 2). Within DE, the mean body weight at phase 3 was significantly lower than at phase 1. No other comparisons among or within groups for men were significant. No significant differences in body weight were observed at the 12-month follow-up among all groups.

Percent body fat was significantly lower in women in DE

Table 2. Baseline Characteristics of Women and Men

Women	D (n = 15)	E (n = 17)	DE (n = 14)
Age (years)	44.0 ± 6.5	42.4 ± 7.3	465.1 ± 4.8
Body Weight (kg)	87.3 ± 12.4	80.6 ± 11.2	81.5 ± 6.9
Height (cm)	168.2 ± 6.4 ^a	162.2 ± 5.7	163.6 ± 4.2
BMI (kg/m ²)	30.8 ± 2.8	30.5 ± 3.0	30.4 ± 2.5
Percent Body Fat	45.4 ± 4.9	45.9 ± 5.4	46.9 ± 4.7
Fat Mass (kg)	39.2 ± 8.1	37.33 ± 8.37	39.11 ± 5.97
Lean Body Mass (kg)	43.1 ± 3.5	43.3 ± 4.9	47.4 ± 6.7 ^b
Men	D (n = 13)	E (n = 17)	DE (n = 14)
Age (years)	43.9 ± 6.5	44.6 ± 8.1	44.9 ± 9.8
Body weight (kg)	96.5 ± 9.1	100.3 ± 14.3	95.7 ± 11.6
Height (cm)	176.3 ± 4.5	177.0 ± 5.7	181.1 ± 5.6 ^c
BMI (kg/m ²)	31.1 ± 3.3	30.5 ± 3.6	30.5 ± 3.2
Percent Body Fat	36.2 ± 4.6	35.1 ± 5.2	36.7 ± 5.6
Fat Mass (kg)	35.1 ± 6.1	33.6 ± 7.5	37.2 ± 9.8
Lean Body Mass (kg)	61.4 ± 6.1	62.0 ± 7.5	63.1 ± 7.6

Values represent means ± Standard Deviation (SD).

D = diet only group, E = exercise only group, DE = diet plus exercise group. BMI = Body Mass Index (weight [kg]/height [m²]).

Changes for Women:

^a D was significantly greater than E (p = 0.02),

^b DE was significantly greater than E and D (p = 0.04).

Changes for Men:

^c DE was significantly greater than D and E (p = 0.04).

Fig 1. Trends in body weight (kg) of women among and within groups over time. Values represent means $\pm$ SD. Month 0 = Baseline, Month 3 = Phase 1, Month 6 = Phase 2, Month 9 = Phase 3, Month 12 = Follow-Up. ^aBody weight for DE was significantly lower than D ($p = 0.04$) and E ($p = 0.02$) at Phase 2. ^bBody weight for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.05$). ^cBody weight for DE was significantly lower than D ($p = 0.03$) and E ($p = 0.02$) at Phase 3. ^dBody weight for DE significantly decreased from Phase 1 to Phase 3 ($p = 0.02$). Note: Baseline body weight for each of the groups was controlled with analysis of covariance (ANCOVA), therefore all subjects started at the same body weight.

Fig 2. Trends in body weight (kg) of men among and within groups over time. Values represent means $\pm$ SD. Month 0 = Baseline, Month 3 = Phase 1, Month 6 = Phase 2, Month 9 = Phase 3, Month 12 = Follow-Up. ^aBody weight for DE was significantly lower than D ($p = 0.04$) and E at Phase 3 ($p = 0.003$). ^bBody weight for DE significantly decreased from Phase 1 to Phase 3 ($p = 0.02$). Note: Baseline body weight for each of the groups was controlled with analysis of covariance (ANCOVA), therefore all subjects started at the same body weight.

than both D and E at phase 2 (Table 3). Fat mass was significantly lower in DE than in D at phase 1. At phase 2, DE was significantly lower than both D and E; while at phase 3 DE was significantly lower than D and E. LBM was similar among groups for women. Within groups, percent body fat was significantly lower at follow-up than at phase 1; while within DE,

percent body fat was significantly lower at phase 2 than at phase 1. Within D, LBM at follow-up was significantly greater than LBM at phase 1.

Percent body fat for men was similar among groups over time while fat mass for DE was significantly lower than D at phase 3 (Table 3). Within groups for men, fat mass for E and DE significantly decreased from phase 1 to phase 2. In addition, fat mass for DE significantly decreased from phase 1 to phase 3. Overall, DE in men had the lowest percent body fat and fat mass at all time points among groups although the differences were not significant. In men, LBM for DE was significantly greater than D at phase 1. Changes in LBM among groups (men) at all other time points were similar.

In women, waist circumference for E was significantly lower than for D at phase 3 (Table 4). Hip circumference was similar among and within groups over time. Waist:hip ratio data indicated that E was significantly lower than D at phase 3. Within groups for women, waist circumferences within E at phase 2, phase 3, and follow-up were significantly lower than phase 1. Waist:hip ratio within DE for women was significantly greater than in phase 2 than phase 1.

In men, waist circumference was significantly lower in DE than D at phase 2, while hip circumference showed no significant changes among groups over time (Table 4). The waist:hip ratio showed no significant differences among or within groups over time in men.

Blood Pressure

Mean systolic blood pressure was similar among groups over time for women (Table 5). Diastolic blood pressure was similar among groups of women at phase 1, phase 2, and phase 3; however, at follow-up, D was significantly lower than E. Within groups (women), systolic blood pressure for D at phase 2 was significantly lower than phase 1. Within groups, diastolic blood pressure for D was significantly lower at follow-up than at phase 1, while E was significantly greater at follow-up than phase 1. There were no statistically significant changes among or within groups with respect to systolic or diastolic blood pressure over time in men (Table 5).

Serum Lipid Concentrations

Serum lipid levels among groups for women and men are shown in Table 6. TC concentrations were significantly greater for women in D than in DE at follow-up. TG and LDL-C levels were similar among groups over time for women. HDL-C levels were significantly greater in E than in D at phase 2, while the TC:HDL-C ratio was significantly greater in D than in E at follow-up.

Within groups (women), TC concentrations were similar over time (Table 6). TG levels within DE at follow-up were significantly greater than at phase 1. LDL-C concentrations were similar over time. HDL-C levels in both D and DE at phase 2 were significantly lower than at phase 1. Within D,

Table 3. Percent Body Fat (%), Fat Mass (kg), and Lean Body Mass (LBM) (kg) for Women and Men

Variable	Group	WOMEN					MEN				
		Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Baseline	Phase 1	Phase 2	Phase 3	Follow-up
Percent	D	46.1 ± 4.9	47.3 ± 0.8	45.7 ± 0.8	46.2 ± 0.8	45.2 ± 0.8 ^a	35.9 ± 5.1	37.3 ± 1.1	36.1 ± 1.1	36.2 ± 1.1	37.1 ± 1.1
Body Fat	E	46.1 ± 4.9	46.3 ± 0.8	45.3 ± 0.9	46.1 ± 0.9	44.5 ± 1.0	35.9 ± 5.1	35.6 ± 0.9	34.5 ± 1.0	35.1 ± 1.0	34.9 ± 1.1
	DE	46.1 ± 4.9	45.0 ± 0.9	42.4 ± 0.9 ^{b,c}	44.4 ± 0.9	44.1 ± 0.9 ^c	35.9 ± 5.1	35.2 ± 1.1	33.2 ± 1.1 ⁱ	33.3 ± 1.1 ^k	34.3 ± 1.1
Fat Mass	D	38.4 ± 7.6	39.7 ± 0.9	38.1 ± 0.9	38.6 ± 0.8	38.0 ± 0.9 ^d	35.2 ± 7.8	35.0 ± 1.3	34.3 ± 1.3	34.7 ± 1.3	35.4 ± 1.3
	E	38.4 ± 7.6	38.9 ± 0.9	37.9 ± 1.0	38.5 ± 1.0	37.4 ± 1.1	35.2 ± 7.8	35.3 ± 1.1	33.6 ± 1.1 ⁱ	33.9 ± 1.2	35.6 ± 1.2
	DE	38.4 ± 7.6	37.0 ± 0.9 ^e	34.2 ± 0.9 ^{f,g}	35.7 ± 0.9 ^h	36.5 ± 0.9	35.2 ± 7.8	33.3 ± 1.2	30.7 ± 1.3 ^m	30.9 ± 1.3 ^{n,o}	32.4 ± 1.3
LBM	D	44.6 ± 5.4	43.6 ± 0.7	44.9 ± 0.7	44.4 ± 0.7	46.7 ± 0.7 ⁱ	62.2 ± 7.0	59.9 ± 1.3	61.2 ± 1.4	60.7 ± 1.4	60.8 ± 1.4
	E	44.6 ± 5.4	44.5 ± 0.7	44.7 ± 0.8	44.3 ± 0.8	45.5 ± 0.9	62.2 ± 7.0	61.7 ± 1.2	62.5 ± 1.2	61.8 ± 1.2	62.4 ± 1.3
	DE	44.6 ± 5.4	44.8 ± 0.7	46.1 ± 0.7	44.3 ± 0.7	45.7 ± 0.8	62.2 ± 7.0	64.1 ± 1.3 ^p	61.9 ± 1.4	61.3 ± 1.4 ^q	62.3 ± 1.4

Values represent means ± SD.

D = diet only group, E = exercise only group, DE = diet plus exercise group.

Changes for Women:

^a Percent body fat for D significantly decreased from Phase 1 to Follow-up ($p = 0.01$),

^b Percent body fat for DE was significantly lower than D ($p = 0.007$) and E ($p = 0.03$) at Phase 2,

^c Percent body fat for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.003$),

^d Fat mass for D significantly decreased from Phase 1 to Follow-up ($p = 0.04$),

^e Fat mass for DE was significantly lower than D at Phase 1 ($p = 0.04$),

^f Fat mass for DE was significantly lower than D ($p = 0.003$) and E ($p = 0.007$) at Phase 2,

^g Fat mass for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.04$),

^h Fat mass for DE was significantly lower than D ($p = 0.02$) and E ($p = 0.04$) at Phase 3,

ⁱ LBM for D significantly increased from Phase 1 to Follow-up ($p = 0.0001$).

Changes for Men:

^j Percent body fat for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.01$),

^k Percent body fat for DE significantly decreased from Phase 1 to Phase 3 ($p = 0.02$),

^l Fat mass for E significantly decreased from Phase 1 to Phase 2 ($p = 0.03$),

^m Fat mass for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.004$),

ⁿ Fat mass for DE significantly decreased from Phase 1 to Phase 3 ($p = 0.01$),

^o Fat mass for DE was significantly lower than D at Phase 3 ($p = 0.04$),

^p LBM for DE was significantly greater than D at Phase 1 ($p = 0.03$),

^q LBM for DE significantly decreased from Phase 1 to Phase 3 ($p = 0.04$).

TC:HDL-C ratio at phase 2, phase 3, and follow-up was significantly greater than at phase 1. Within E and DE, the TC:HDL-C ratio was significantly greater at phase 2 than at phase 1.

There were no significant differences in men among groups with respect to TC, TG, and LDL-C levels over time (Table 6). HDL-C levels were significantly lower in D than in both E and DE at phase 3, while the TC:HDL-C ratio was similar among groups over time in men. Within groups (for men), no significant differences were observed with respect to TC and TG levels over time. However, within D and E, LDL-C levels were significantly greater at follow-up than at phase 1. Within D, HDL-C levels were significantly greater at phase 1 than at phase 2, phase 3, and follow-up. The TC:HDL-C ratio within D was significantly greater at phase 2 and phase 3 than at phase 1.

Serum Leptin Concentrations

Table 7 lists the mean change in serum leptin levels (ng/mL) (after six months) of the all three groups for women and men. No significant changes were observed in serum leptin levels among all three groups. Within D and DE, however, serum

leptin levels significantly decreased from baseline. No significant changes were observed serum leptin levels among groups for men. Serum leptin levels were significantly decreased within E from baseline in men.

Fitness Levels

Fitness results are shown for women and men in all groups in Table 8. Fitness test time analyses showed that women in both E and DE performed the one mile fitness test in significantly less time than D at phase 1, phase 2, phase 3, and follow-up. Fitness test times for women within D at phase 2, phase 3, and follow-up were significantly lower than the fitness test time at phase 1. For women within E, fitness test times at phase 2, phase 3, and follow-up were significantly lower than the fitness test time at phase 1. Within DE, the fitness test time at phase 2 and follow-up was significantly lower than at phase 1. Fitness test heart rate (Table 8) was not different among groups over time. For women within E, fitness test heart rate at phase 3 and follow-up were significantly greater than phase 1.

The duration (time) to complete the fitness test was significantly greater for men in D than in both E and DE at phase 1, phase 2, and phase 3 (Table 8). Men in D took a significantly

Table 4. Waist and Hip Circumference Measurements (cm) for Women and Men

Group	WOMEN					MEN				
	Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Baseline	Phase 1	Phase 2	Phase 3	Follow-up
Waist	D	95.3 ± 9.1	97.4 ± 1.6	94.2 ± 1.6	97.3 ± 1.6	96.2 ± 1.6	107.4 ± 1.4	106.6 ± 1.4	107.3 ± 1.4	106.5 ± 1.4
	E	95.3 ± 9.1	96.6 ± 1.6	91.7 ± 1.9 ^a	91.2 ± 1.9 ^b	91.4 ± 2.2 ^c	106.3 ± 1.3	105.4 ± 1.3	107.0 ± 1.3	105.4 ± 1.4
Hip	DE	95.3 ± 9.1	93.9 ± 1.6	95.4 ± 1.6	93.1 ± 1.7	93.2 ± 1.8	106.6 ± 1.1	101.9 ± 1.4 ^f	105.8 ± 1.4	104.7 ± 1.5
	D	113.5 ± 7.1	114.1 ± 1.2	112.7 ± 1.0	111.9 ± 1.1	113.7 ± 1.1	109.0 ± 7.4	108.3 ± 1.5	109.5 ± 1.6	108.2 ± 1.6
E	E	113.5 ± 7.1	112.8 ± 1.0	110.6 ± 1.3	110.9 ± 1.3	111.5 ± 1.5	109.0 ± 7.4	110.3 ± 1.4	110.4 ± 1.4	109.6 ± 1.6
	DE	113.5 ± 7.1	112.9 ± 1.1	110.7 ± 1.1	110.5 ± 1.1	110.8 ± 1.1	109.0 ± 7.4	108.4 ± 1.5	109.2 ± 1.6	109.6 ± 1.7
Waist:Hip Ratio	D	0.85 ± 0.06	0.85 ± 0.01	0.83 ± 0.01	0.86 ± 0.01	0.84 ± 0.01	0.98 ± 0.05	0.99 ± 0.01	0.97 ± 0.01	0.98 ± 0.01
	E	0.85 ± 0.06	0.83 ± 0.01	0.83 ± 0.01	0.83 ± 0.01	0.82 ± 0.02	0.98 ± 0.05	0.97 ± 0.01	0.96 ± 0.01	0.96 ± 0.01
DE	DE	0.85 ± 0.06	0.83 ± 0.01	0.86 ± 0.01 ^d	0.84 ± 0.01 ^e	0.84 ± 0.01	0.98 ± 0.05	0.95 ± 0.01	0.97 ± 0.01	0.96 ± 0.01

Values represent means ± SD.

D = diet only group, E = exercise only group, DE = diet plus exercise group.

Changes for Women:

^a Waist circumference for E significantly decreased from Phase 1 to Phase 2 ($p = 0.03$).^b Waist circumference for E significantly decreased from Phase 1 to Phase 3 ($p = 0.02$).^c Waist circumference for E significantly decreased from Phase 1 to Follow-up ($p = 0.04$).^d Waist:hip ratio for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.03$).^e Waist:hip ratio for E was significantly lower than D at Phase 3 ($p = 0.04$).

Changes for Men:

^f Waist circumference for DE was significantly lower than D at Phase 2 ($p = 0.03$).

greater time to complete the fitness test than DE at follow-up. For men within D, time to complete the fitness test at phase 3 and follow-up was significantly lower than at phase 1.

Fitness test heart rate immediately post-exercise was similar among the groups of men at phase 1, phase 2, and phase 3. At follow-up, men in D had a significantly lower heart rate immediately post-exercise than DE. For men within D, heart rate at follow-up was significantly lower than at phase 1. Within DE, heart rate at phase 3 was significantly lower than at phase 1.

Dietary Intake

No significant differences in average energy intake were observed among and within groups of women over time (Table 9). Average protein intake was significantly greater for women in D than DE at follow-up. Total fat intake was similar among and within groups over time. Saturated fat intake was significantly greater for women in D than E and DE at follow-up (Table 9).

Men in E consumed significantly more energy (kilojoules [kJ]) than D at Phase 3 (Table 9). There were no statistically significant differences among and within groups of men with respect to protein and fat intake. Men in E consumed significantly more carbohydrate than D at Phase 3.

DISCUSSION

The purpose of this study was to determine the effects of diet only (D), exercise only (E), and diet plus exercise (DE) on body weight, body composition, blood pressure measurements, serum lipid and leptin levels, and fitness levels of moderately obese sedentary adults over one year.

Anthropometric Measurements

Body Weight. It is possible that the greater body weight regain in DE among men, as well as D and E among women could have been due to lack of motivation of the subjects upon completion of the nutrition classes. The reduced contact between the subjects and researchers may have been a factor. On a long-term basis, the restraint required to maintain new dietary habits may have become burdensome [3]. Lack of social support among members of all the treatment groups may have led to the body weight regain after six months upon completion of the nutrition classes and supervised exercise sessions [3]. Similar to Skender et al. [3] it is unclear why DE regained the greatest amount of body weight among groups in both men and women from phase 3 to follow-up. This could have been due to a greater degree of compromise in DE compared to D in implementing the dietary modification, because this group was receiving both dietary and exercise interventions. This may have resulted in a larger relapse in DE compared to D.

Over the length of the study, E maintained their body weight

Table 5. Systolic and Diastolic Blood Pressure Measurements (mm Hg) for Women and Men

Group		WOMEN					MEN				
		Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Baseline	Phase 1	Phase 2	Phase 3	Follow-up
Systolic	D	126.8 ± 13.5	129.9 ± 3.1	123.1 ± 3.1 ^a	127.1 ± 3.1	125.3 ± 3.1	147.7 ± 21.6	132.5 ± 3.8	129.7 ± 3.9	132.0 ± 3.9	134.4 ± 3.9
	E	126.8 ± 13.5	129.7 ± 3.1	127.7 ± 3.7	130.8 ± 3.7	129.8 ± 4.1	147.7 ± 21.6	129.6 ± 3.4	132.4 ± 3.5	134.8 ± 3.5	133.3 ± 3.8
	DE	126.8 ± 13.5	125.9 ± 3.2	123.7 ± 3.1	125.5 ± 3.1	128.9 ± 3.3	147.7 ± 21.6	131.3 ± 3.7	135.9 ± 3.9	131.0 ± 3.9	132.1 ± 4.1
Diastolic	D	80.7 ± 8.8	84.4 ± 2.1	81.7 ± 2.1	80.9 ± 2.1	78.1 ± 2.1 ^{b,c}	94.6 ± 14.4	85.8 ± 2.4	86.2 ± 2.5	86.6 ± 2.5	85.1 ± 2.5
	E	80.7 ± 8.8	79.5 ± 2.2	81.3 ± 2.6	82.2 ± 2.6	87.0 ± 2.9 ^d	94.6 ± 14.4	82.5 ± 2.2	86.9 ± 2.3	85.2 ± 2.3	86.7 ± 2.4
	DE	80.7 ± 8.8	79.2 ± 2.2	76.4 ± 2.2	79.7 ± 2.2	81.9 ± 2.3	94.6 ± 14.4	85.7 ± 2.3	84.9 ± 2.5	82.1 ± 2.5	82.3 ± 2.6

Values represent means ± SD.

D = diet only group, E = exercise only group, DE = diet plus exercise group.

Changes for Women:

^a Systolic blood pressure for D significantly decreased from Phase 1 to Phase 2 ($p = 0.04$),

^b Diastolic blood pressure for D significantly decreased from Phase 1 to Follow-up ($p = 0.007$),

^c Diastolic blood pressure for D was significantly lower than E at Follow-up ($p = 0.01$),

^d Diastolic blood pressure for E significantly increased from Phase 1 to Follow-up ($p = 0.01$).

among men and women. Most body weight maintainers have been reported to exercise regularly, whereas few relapsers did [12]. It is suggested that exercise may elevate mood and feelings of well-being, which may facilitate other positive behaviors conducive to successful maintenance of body weight loss [12]. One important factor that was not controlled in this study was the subjects' perception of and adherence to their respective regimens upon completion of the nutrition classes and supervised exercise sessions. Failure to control for this in the present study, by means of a questionnaire has led to speculation about the weight regain among the groups.

As in our study, Skender et al. [3] reported no significant difference in mean body weight change from baseline to two years among their three intervention groups. A longer participation in supervised dietary and/or exercise interventions might have enhanced the differences in body weight among groups observed at phase 2 and phase 3 in men and women.

Percent Body Fat. Similar to our results, Wilmore et al. [13] observed a non-significant (0.9%) decrease in percent body fat over 20 weeks in 258 mildly obese exercising men. Our findings are also in agreement with Kraemer et al. [14] who reported that men in D and DE had significant decreases of 3.6% and 4.7% body fat, respectively, at the end of their 12-week study. Greater percent body fat losses were observed in Kraemer et al.'s [14] study possibly because, in addition to following their dietary regimen, subjects in D were weighed weekly to ensure a body weight loss of 0.5 to 1.0 kg per week, and were given individual counseling if this body weight loss was not achieved. This may have led to greater adherence to the dietary regimen, and consequently, a greater decline in percent body fat than in our study. Kraemer et al.'s [14] study had an exercise regimen consisting of a variety of endurance activities which included a cross-training mix of treadmill walking/jogging, stationary cycling, seated rowing, stationary stair climbing and weight training. It is possible that exercising subjects utilized more muscle groups in their study, resulting in greater percent body fat losses [14].

Fat Mass. Findings of lower fat mass within groups over time are consistent with studies [15,16] that found that fat mass was significantly reduced for all groups after 12 weeks in men and women. Kraemer et al. [15] did not observe any significant differences in the magnitude of change in fat mass among groups over 12 weeks in women. In contrast to our study, Kraemer et al. [15] reported that a dietary restriction plus exercise regimen had no significant effect on fat mass compared with dietary restriction without exercise in women. Subjects in our study had a mean fat mass of 38.5 kg at baseline, while in Kramer et al.'s [15] investigation, the mean fat mass at baseline was 29.5 kg. It is probable that we observed significant changes because subjects had a greater fat mass at baseline. Kraemer et al. [15] performed their study over 12 weeks, which may not have been a sufficient length of time to elicit any changes in fat mass among treatment groups.

Lean Body Mass (LBM). All groups experienced similar changes in LBM among men and women over time, which is in agreement with Utter et al. [16] who studied 91 obese women, and reported that exercise training alone or in combination with moderate energy restriction was associated with no significant change in LBM [15]. Utter et al.'s [16] study was only 12 weeks, which may not have been a sufficient duration to elicit significant changes in LBM among groups. They reported that the net energy expenditure for the exercise sessions of 783 kJ/session was relatively small [16]. One short-coming of our study is that the net energy expenditure per exercise session was not accounted, which would be important to ascertain the intensity level of each subject's exercise session. This would have enabled us to identify an exercise intensity at which a change in LBM might have been observed. In their meta-analysis of 28 studies, Garrow and Summerbell [17] concluded that aerobic exercise training may reduce diet-induced LBM loss by 0.5 to 1.2 kg in women and men, respectively. Adding resistance exercise, however, appears more useful than moderate aerobic exercise alone in protecting diet-induced losses in LBM [14,16,18]. Kraemer et al. [14] have shown that the

Table 6. Serum Lipid Levels (mmol/L) for Women and Men

Variable	Group	WOMEN					MEN				
		Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Baseline	Phase 1	Phase 2	Phase 3	Follow-up
TC	D	5.41 ± 0.91	5.45 ± 0.14	5.28 ± 0.14	5.51 ± 0.14	5.67 ± 0.14 ^a	5.38 ± 1.25	5.14 ± 0.21	5.13 ± 0.21	5.21 ± 0.21	5.39 ± 0.21
	E	5.41 ± 0.91	5.35 ± 0.14	5.47 ± 0.17	5.52 ± 0.19	5.44 ± 0.17	5.38 ± 1.25	5.22 ± 0.18	5.20 ± 0.20	5.42 ± 0.21	5.20 ± 0.18
	DE	5.41 ± 0.91	5.12 ± 0.15	5.34 ± 0.15	5.45 ± 0.16	5.23 ± 0.15	5.38 ± 1.25	5.27 ± 0.19	5.11 ± 0.21	5.39 ± 0.22	5.34 ± 0.22
TG	D	1.35 ± 0.79	1.33 ± 0.12	1.26 ± 0.12	1.31 ± 0.12	1.36 ± 0.12	1.89 ± 1.38	1.86 ± 0.23	1.70 ± 0.24	1.89 ± 0.24	1.83 ± 0.24
	E	1.35 ± 0.79	1.14 ± 0.11	1.29 ± 0.14	1.30 ± 0.15	1.38 ± 0.14	1.89 ± 1.38	1.69 ± 0.21	1.57 ± 0.22	1.65 ± 0.22	1.96 ± 0.21
	DE	1.35 ± 0.79	1.35 ± 0.79	1.01 ± 0.12	1.11 ± 0.13	1.19 ± 0.13 ^b	1.89 ± 1.38	1.85 ± 0.22	1.65 ± 0.23	1.86 ± 0.24	1.69 ± 0.24
LDL-C	D	3.20 ± 0.84	3.44 ± 0.12	3.49 ± 0.12	3.61 ± 0.13	13.64 ± 0.12	3.27 ± 1.13	3.13 ± 0.13	3.36 ± 0.13	3.39 ± 0.13	3.48 ± 0.13 ^l
	E	3.20 ± 0.84	3.32 ± 0.12	3.42 ± 0.15	3.46 ± 0.17	3.35 ± 0.15	3.27 ± 1.13	3.25 ± 0.12	3.35 ± 0.13	3.44 ± 0.14	3.64 ± 0.13 ^m
	DE	3.20 ± 0.84	3.32 ± 0.13	3.58 ± 0.14	3.59 ± 0.15	3.30 ± 0.13	3.27 ± 1.13	3.36 ± 0.13	3.29 ± 0.13	3.46 ± 0.15	3.42 ± 0.14
HDL-C	D	1.58 ± 0.32	1.40 ± 0.05	1.21 ± 0.05 ^c	1.33 ± 0.05	1.34 ± 0.05 ^c	1.29 ± 0.26	1.19 ± 0.04	1.01 ± 0.04 ⁿ	0.97 ± 0.04 ^{o,p}	1.10 ± 0.04 ^q
	E	1.58 ± 0.32	1.47 ± 0.05	1.37 ± 0.05 ^d	1.44 ± 0.06	1.45 ± 0.06	1.29 ± 0.26	1.10 ± 0.03	1.05 ± 0.04	1.09 ± 0.04	1.11 ± 0.03
	DE	1.58 ± 0.32	1.41 ± 0.05	1.32 ± 0.05 ^e	1.36 ± 0.05	1.35 ± 0.05	1.29 ± 0.26	1.14 ± 0.04	1.07 ± 0.04	1.11 ± 0.04	1.16 ± 0.04
TC: HDL-C	D	0.02 ± 0.09	0.004 ± 0.09	0.004 ± 0.11 ^f	0.004 ± 0.10 ^g	0.004 ± 0.10 ^{h,i}	0.11 ± 0.04	0.12 ± 0.01	0.14 ± 0.01 ^f	0.14 ± 0.01 ^s	0.13 ± 0.01
	E	0.02 ± 0.09	0.004 ± 0.09	0.005 ± 0.11	0.005 ± 0.11	0.005 ± 0.10	0.11 ± 0.04	0.13 ± 0.01	0.14 ± 0.01	0.14 ± 0.01	0.14 ± 0.01
	DE	0.02 ± 0.09	0.005 ± 0.09	0.005 ± 0.11 ⁱ	0.005 ± 0.11 ^k	0.005 ± 0.10	0.11 ± 0.04	0.13 ± 0.01	0.13 ± 0.01	0.14 ± 0.01	0.12 ± 0.01

Values represent means ± SD.

TC = Serum Total Cholesterol Levels, D = diet only group, E = exercise only group, DE = diet plus exercise group, TG = Serum Triglyceride Levels, LDL-C = Serum Low Density Lipoprotein Cholesterol Levels, HDL-C = Serum High Density Lipoprotein Cholesterol Levels, TC:HDL-C = Total Cholesterol to High Density Lipoprotein Cholesterol Ratio.

Changes for Women:

- ^a TC for D were significantly greater than DE at Follow-up ($p = 0.03$),
- ^b TG for DE significantly increased from Phase 1 to Follow-up ($p = 0.001$),
- ^c HDL-C for D significantly decreased from Phase 1 to Phase 2 ($p = 0.0001$),
- ^d HDL-C for E was significantly greater than D at Phase 2 ($p = 0.03$),
- ^e HDL-C for DE significantly decreased from Phase 1 to Phase 2 ($p = 0.05$),
- ^f TC:HDL-C ratio for D significantly increased from Phase 1 to Phase 2 ($p = 0.0001$),
- ^g TC:HDL-C ratio for D significantly increased from Phase 1 to Phase 3 ($p = 0.01$),
- ^h TC:HDL-C ratio for D significantly increased from Phase 1 to Follow-up ($p = 0.001$),
- ⁱ TC:HDL-C ratio for D was significantly greater than E at Follow-up ($p = 0.04$),
- ^j TC:HDL-C ratio for DE significantly increased from Phase 1 to Phase 2 ($p = 0.005$),
- ^k TC:HDL-C ratio for DE significantly increased from Phase 1 to Phase 3 ($p = 0.03$).

Changes for Men:

- ^l LDL-C for D significantly increased from Phase 1 to Follow-up ($p = 0.03$),
- ^m LDL-C for E significantly increased from Phase 1 to Follow-up ($p = 0.01$),
- ⁿ HDL-C for D significantly decreased from Phase 1 to Phase 2 ($p = 0.0001$),
- ^o HDL-C for D were significantly lower than DE ($p = 0.02$) and E ($p = 0.03$) at Phase 3,
- ^p HDL-C for D significantly decreased from Phase 1 to Phase 3 ($p = 0.0001$),
- ^q HDL-C for D significantly decreased from Phase 1 to Follow-up ($p = 0.003$),
- ^r TC:HDL-C ratio for D significantly increased from Phase 1 to Phase 2 ($p = 0.006$),
- ^s TC:HDL-C ratio for D significantly increased from Phase 1 to Phase 3 ($p = 0.001$).

Table 7. Among and Within-Group Changes in Serum Leptin Levels (ng/mL) in Women and Men from Baseline to Six Months

	D	E	DE
Women			
Among-Group Changes	-21.12 ± 5.0	-27.62 ± 6.1	-33.74 ± 5.1
Within-Group Changes	-31.35 ± 53.4 ^a	-20.56 ± 46.0	-27.61 ± 19.5 ^a
Men			
Among-Group Changes	1.98 ± 3.01	-4.24 ± 2.58	-3.61 ± 3.14
Within-Group Changes	2.11 ± 13.84	-4.42 ± 7.49 ^b	-3.54 ± 7.48

Values represent mean differences ± SD.

D = diet only group, E = exercise only group, DE = diet plus exercise group.

Changes for Women:

- ^a Significantly lower from baseline within D ($p = 0.05$) and DE ($p = 0.0003$).

Changes for Men:

- ^b Significantly lower from baseline within E ($p = 0.038$) in men.

Table 8. Fitness Test Time (minutes) and Heart Rate (beats per minute) Measurements for Women and Men

Group	WOMEN					MEN					
	Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Baseline	Phase 1	Phase 2	Phase 3	Follow-up	
Fitness Test Time	D	13.4 ± 3.2	13.9 ± 0.5 ^a	11.4 ± 0.5 ^{b,c}	10.9 ± 0.5 ^{d,e}	10.7 ± 0.5 ^{f,g}	12.1 ± 4.5	12.1 ± 1.2 ^o	10.1 ± 1.1 ^p	9.1 ± 1.0 ^q	9.2 ± 1.0 ^r
	E	13.4 ± 3.2	9.6 ± 0.5	8.2 ± 0.6 ^h	7.3 ± 0.5 ⁱ	8.1 ± 0.6 ^j	12.1 ± 4.5	6.6 ± 0.6	6.7 ± 0.7	6.3 ± 0.7	7.1 ± 0.7
	DE	13.4 ± 3.2	9.0 ± 0.5	7.9 ± 0.5 ^k	8.2 ± 0.5	7.8 ± 0.5 ^l	12.1 ± 4.5	7.7 ± 0.7	6.9 ± 0.7	6.3 ± 0.8	6.4 ± 0.8
Heart Rate	D	136.3 ± 23.8	146.1 ± 5.6	141.9 ± 5.3	144.7 ± 5.3 ^m	142.8 ± 5.6 ⁿ	133.1 ± 19.8	149.8 ± 6.6	139.8 ± 11.5	132.8 ± 11.5	115.4 ± 6.8 ^{s,t}
	E	136.3 ± 23.8	134.1 ± 5.1	142.7 ± 6.0	149.8 ± 6.0	153.5 ± 5.6	133.1 ± 19.8	144.5 ± 4.7	143.4 ± 5.2	132.1 ± 5.4	141.0 ± 6.6
	DE	136.3 ± 23.8	136.3 ± 4.6	136.7 ± 4.6	147.2 ± 4.6	141.3 ± 4.6	133.1 ± 19.8	149.3 ± 4.5	149.0 ± 4.6	134.5 ± 4.9 ^u	148.2 ± 6.6

Values represent means ± SD.

D = diet only group, E = exercise only group, DE = diet plus exercise group.

Changes for Women:

^a Fitness test time for D was significantly greater than both E (p = 0.0001) and DE (p = 0.0001) at Phase 1,^b Fitness test time for D was significantly greater than both E (p = 0.0002) and DE (p = 0.0001) at Phase 2,^c Fitness test time for D significantly decreased from Phase 1 to Phase 2 (p = 0.0001),^d Fitness test time for D was significantly greater than both E (p = 0.0001) and DE (p = 0.0003) at Phase 3,^e Fitness test time for D significantly decreased from Phase 1 to Phase 3 (p = 0.0001),^f Fitness test time for D was significantly greater than both E (p = 0.001) and DE (p = 0.0001) at Follow-up,^g Fitness test time for D significantly decreased from Phase 1 to Follow-up (p = 0.0001),^h Fitness test time for E significantly decreased from Phase 1 to Phase 2 (p = 0.04),ⁱ Fitness test time for E significantly decreased from Phase 1 to Phase 3 (p = 0.0003),^j Fitness test time for E significantly decreased from Phase 1 to Follow-up (p = 0.02),^k Fitness test time for DE significantly decreased from Phase 1 to Phase 2 (p = 0.04),^l Fitness test time for DE significantly decreased from Phase 1 to Follow-up (p = 0.02),^m Fitness test heart rate for D significantly increased from Phase 1 to Phase 3 (p = 0.04),ⁿ Fitness test heart rate for D significantly increased from Phase 1 to Follow-up (p = 0.008),

Changes for Men:

^o Fitness test time for D was significantly greater than E (p = 0.0002) and DE (p = 0.002) at Phase 1,^p Fitness test time for D was significantly greater than E (p = 0.008) and DE (p = 0.02) at Phase 2,^q Fitness test time for D was significantly greater than E (p = 0.02) and DE (p = 0.03) at Phase 3,^r Fitness test time for D was significantly greater than DE at Follow-up (p = 0.03),^s Fitness test heart rate for D was significantly lower than DE at Follow-up (p = 0.02),^t Fitness test heart rate for D significantly decreased from Phase 1 to Follow-up (p = 0.04),^u Fitness test heart rate for DE significantly decreased from Phase 1 to Phase 3 (p = 0.02).

Table 9. Energy (kilojoules [kJ]), Protein (grams [g]), Total Fat (g), and Carbohydrate (g) Intake of Women and Men

Group	WOMEN						MEN					
	Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Baseline	Phase 1	Phase 2	Phase 3	Follow-up	Phase 1	Phase 2
Energy (kJ)												
D	8489 ± 2721	7147 ± 566	7652 ± 566	6594 ± 669	7725 ± 639	9426 ± 2974	8997 ± 754	9417 ± 757	7744 ± 797	7634 ± 984		
E	8489 ± 2721	7947 ± 579	8285 ± 635	7508 ± 669	6946 ± 710	9426 ± 2974	10165 ± 718	10424 ± 727	10750 ± 796 ^b	9128 ± 981		
DE	8489 ± 2721	6706 ± 616	7463 ± 608	6602 ± 680	6723 ± 767	9426 ± 2974	9449 ± 689	9081 ± 722	9425 ± 982	8338 ± 1251		
Protein (g)												
D	80.1 ± 29.4	66.6 ± 6.0	74.1 ± 6.0	71.6 ± 7.4	84.0 ± 6.9 ^a	86.9 ± 27.5	87.4 ± 7.9	90.7 ± 7.9	86.1 ± 8.5	92.4 ± 10.5		
E	80.1 ± 29.4	74.5 ± 6.2	80.0 ± 6.9	70.9 ± 7.4	68.7 ± 7.8	86.9 ± 27.5	105.4 ± 7.5	101.6 ± 7.5	97.7 ± 8.4	95.2 ± 10.5		
DE	80.1 ± 29.4	63.4 ± 6.7	75.9 ± 6.6	65.2 ± 7.4	59.7 ± 8.5	86.9 ± 27.5	92.9 ± 7.2	88.1 ± 7.5	89.3 ± 10.5	87.8 ± 13.4		
Total Fat (g)												
D	80.1 ± 35.9	56.9 ± 7.1	64.1 ± 7.2	49.3 ± 8.4	77.3 ± 8.1	77.9 ± 34.0	74.9 ± 8.6	85.9 ± 8.6	64.2 ± 9.1	65.9 ± 11.3		
E	80.1 ± 35.9	73.3 ± 7.2	79.2 ± 8.0	66.0 ± 8.5	63.7 ± 8.9	77.9 ± 34.0	72.8 ± 8.2	83.1 ± 8.3	76.6 ± 9.1	52.4 ± 11.2		
DE	80.1 ± 35.9	53.5 ± 7.8	60.0 ± 7.2	53.5 ± 8.6	61.5 ± 9.8	77.9 ± 34.0	73.5 ± 7.9	72.6 ± 8.2	69.1 ± 11.2	66.5 ± 14.4		
Carbohydrate (g)												
D	249.4 ± 76.8	243.2 ± 21.3	250.6 ± 21.3	221.4 ± 25.2	218.0 ± 24.0	293.4 ± 91.5	274.9 ± 26.9	274.3 ± 26.9	228.0 ± 28.3	231.5 ± 34.5		
E	249.4 ± 76.8	233.7 ± 22.2	237.7 ± 24.2	235.9 ± 25.6	205.1 ± 26.9	293.4 ± 91.5	326.4 ± 25.6	314.3 ± 25.9	363.5 ± 28.2 ^c	323.6 ± 34.3		
DE	249.4 ± 76.8	221.7 ± 22.9	237.5 ± 22.8	202.8 ± 25.3	203.9 ± 28.6	293.4 ± 91.5	299.8 ± 24.9	278.8 ± 25.9	298.3 ± 34.4	256.5 ± 43.4		

Values represent means ± SD.

D = diet only group, E = exercise only group, DE = diet plus exercise group.

Changes for Women:

^a Protein intake for D was significantly greater than DE at Follow-up ($p = 0.03$).

Changes for Men:

^b Energy intake for E was significantly greater than D at Phase 3 ($p = 0.01$).^c Carbohydrate intake for E was significantly greater than D at Phase 3 ($p = 0.001$).

inclusion of both endurance and heavy resistance training three times per week resulted in a nearly complete preservation of LBM in a group of overweight men. Geliebter et al. [19] have similarly shown that strength training significantly preserves LBM relative to either aerobic exercise or no exercise in diet-restricting obese subjects. Because our study was solely comprised of aerobic exercise, LBM was not as well preserved.

Body Circumferences. Findings of decreased body circumferences during exercise are consistent with Wilmore et al. [12] who observed that, after 20 weeks of aerobic exercise, there were small but significant changes in waist and hip circumferences in men. The lower waist:hip ratio in E in our study is in agreement with researchers who have suggested that physical activity may be particularly valuable in reducing visceral abdominal fat [4,20,21]. These researchers [4,20,21] have shown that physically active men and women have lower waist:hip ratios than their sedentary counterparts.

Blood Pressure Measurements

Why some and not all of the blood pressure variables were significantly reduced within the groups among women, unlike the observation in men, from baseline to one year is unclear. However, these results are in agreement with other researchers [19,20] who have reported significant improvements in blood pressure among groups involved in increased physical activity and/or dietary interventions compared to control groups. For example, Wood and colleagues [20] found a significant reduction resting systolic and diastolic blood pressure in men and women in both D and DE compared to control groups after one year. Wood et al. [20] have suggested that weight loss on a fat-reduced prudent diet results in a sustained reduction in blood pressure even in overweight people who were initially within the normotensive range.

Serum Lipid Levels

The lipid responses of similar TC levels, TG levels, and increased LDL-C levels among men over time are in contrast to the findings of Kraemer et al. [13] who reported significant declines in TC levels, TG levels and LDL-C levels in D, E and DE plus Strength training (DES), while HDL-C remained unchanged from baseline to 12 weeks in men. Kraemer et al. [13] reported the greatest reductions in TC and LDL-C levels in individuals who reduced body weight to the greatest extent. In the present study however, subjects experienced a much smaller body weight loss at 12 weeks (phase 1). The small body weight loss over the course of the present study may not have translated into meaningful improvements in serum lipid profiles within groups over time.

Results of body weight loss on dyslipidemia are not consistent. This is probably because of confounding factors such as composition of diet, saturated fat intake, level of physical activity, and fitness levels [22]. Vasankari et al. [23] reported that a 10-month exercise program decreased LDL-C levels in

men and women by 10% and 11%, respectively; increased HDL-C levels by 15% in men and 5% in women, while TC levels and TG levels remained unchanged. The observations from the current study among men are in agreement with those by Wood et al. [20] who compared diet alone to diet and exercise during weight loss. Persons who exercised during weight loss had more healthy lipid profiles, in particular higher HDL-C levels, than persons who lost body weight through energy restriction alone. However, according to Vasankari et al. [23], a 10-month exercise program resulted in modest body weight losses of 3% in men and 2.3% in women, which were much smaller than body weight losses reported by Kraemer et al. [14]. It is possible that the subjects in their study [14] may still have been losing body weight. This may induce a non-steady state that has transient effects on TC levels and LDL-C levels therefore, it is difficult to make conclusions regarding changes in blood lipid levels after only 12 weeks [14].

Lower TC levels in DE than D were expected because body weight loss resulting from diet modification and increased physical activity has been known to reduce risk factors for coronary heart disease (CHD) [17]. Although LDL-C levels were not reduced among and within groups in women, greater body weight losses might have produced a reduction in LDL-C levels because this has been associated with body weight loss in other studies [13,24].

Although exercise typically increases HDL-C levels, this finding is in agreement with researchers who have reported that HDL-C levels may actually decline during the active phase of body weight loss, particularly when a fat-reduced diet is employed [13,20,22]. This initial decline is reversed during the weight maintenance phase in both men and women [20,22,25,26].

Serum Leptin Levels

Previous researchers have demonstrated that weight loss achieved through diet alone and exercise alone reduces serum leptin concentration [27–32]. Although factors that may regulate leptin concentrations have been proposed, it is not known exactly what influences the changes in circulating levels of leptin [27,29,33–35]. In all three groups, fat mass and serum leptin levels decreased, with the greatest reduction in fat mass was in DE. This implies that changes in body composition may have an influence on serum leptin levels [27], and that both interventions combined may have acted synergistically and resulted in improving insulin sensitivity [27,35]. Therefore, insulin and glucose levels may be other factors that could have been directly influenced by the diet and exercise intervention and, in turn, may have resulted in the reduction of serum leptin levels observed in our study. Because we did not assess insulin sensitivity, insulin or glucose levels, we can not speculate on this connection with leptin.

Previous researchers have proposed that the reductions in circulating leptin levels in response to energy-restrictive diets

or increased exercise are dependent upon reductions in adiposity and may be influenced by gender [27–31,38]. It is possible, however, that other parameters may have affected the change in serum leptin levels of females in D, including: metabolic hormones (e.g., insulin, cortisol, epinephrine, and neuropeptides) [35], cytokines, leptin-binding proteins, and/or leptin clearance [39]. Metabolic hormones influence food intake, energy expenditure, and body weight. Cytokines may be involved in the expression of metabolic factors (e.g., insulin, fibrinolytic factors, and serum triglycerides) that may also influence leptin production [36].

Within E, only the males showed a significant decrease in serum leptin concentration, despite having no significant changes in body composition. Exercise may have had an impact on the levels of the male hormone testosterone, which has been proposed to be one of the major regulatory factors of serum leptin levels in men [39]. Serum testosterone levels may regulate the expression of mRNA in fat cells [39]. In primary human cell lines, serum testosterone has been shown to reduce leptin secretion and mRNA by 62% [39]. Hence, it is possible that the reduction in serum leptin levels observed in males in E, which was not observed in females in E, was due to the effect of testosterone suppressing the expression of mRNA in the fat cells or directly suppressing leptin secretion [39].

Dietary Intake

Dietary intake remained fairly constant among all groups over time, though we expected D and DE to lower their overall energy intake. Although low carbohydrate diets may initially decrease lipid levels compared to lower fat diets, it appears that the weight loss causes the greatest effect on lipid levels and other metabolic measurements [40]. The fact that D and DE did not significantly change their dietary intakes over time may have been due to a lack of a strong behavioral component, though there was a strong educational component to the study.

CONCLUSION

In conclusion, a supervised exercise program combined with nutritional modifications was effective in achieving greater body weight losses among sedentary overweight men and women during the supervised phase of the study. No additional benefits were detectable over exercise alone or diet alone with regards to changes in body composition, blood pressure measurements, and blood lipid and leptin levels at one year (or six months with regard to leptin levels) in men and women. Our study emphasizes the need for individuals to seek continued support of supervised exercise groups to continue losing or maintain body weight.

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